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A Summary of Current Program and
Preliminary Report of Progress

SUGAR CROPS RESEARCH

of the

United States Department of Agriculture

and related work of the

State Agricultural Experiment Stations

This progress report is primarily a research tool for use of scientists and administrators in program coordination, development, and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs.

The summaries of research progress include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed, will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members, and others having a special interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of U.S.D.A. and cooperative research issued during the past year. Current agricultural research findings are also published in the monthly U.S.D.A. publications, Agricultural Research and The Farm Index.

UNITED STATES DEPARTMENT OF AGRICULTURE
Washington, D. C. 20250

December 1, 1967

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CURRENT SERIAL RECORDS

RESEARCH ADVISORY COMMITTEES

The following Research Advisory Committees were established pursuant to Title III of the Research and Marketing Act of 1946:

1. Farm Resources & Facilities
2. Utilization Research & Develop.
3. Human Nutrition & Consumer Use
4. Marketing
5. Agricultural Economics
6. Forestry
7. Animal & Animal Products
8. Cotton
9. Grain and Forage Crops
10. Horticultural Crops
11. Oilseed and Peanut Crops
12. Plant Science & Entomology
13. Sugar Crops
14. Tobacco

The source materials used by the advisory committees include organizational unit progress reports and subject matter progress reports. The latter contain information which was first reported in the organizational reports and has been assembled for use by commodity committees. The number prefixes shown below refer to advisory committees listed above.

ORGANIZATIONAL UNIT PROGRESS REPORTS

Agricultural Research Service (ARS)

- 1 - Agricultural Engineering
- 1 - Soil & Water Conservation
- 2 - Utilization -- Eastern
- 2 - Utilization -- Northern
- 2 - Utilization -- Southern
- 2 - Utilization -- Western
- 3 - Human Nutrition
- 3 - Consumer & Food Economics
- 4 - Market Quality
- 4 - Transportation & Facilities
- 7 - Animal Husbandry
- 7 - Animal Disease & Parasite
- 12 - Crops
- 12 - Entomology

Economic Research Service (ERS)

- 5 - Economic Development
- 4, 5 - Marketing Economics
- 5 - Farm Production Economics
- 5 - Economic & Statistical Analysis
- 5 - Foreign Development & Trade
- 5 - Foreign Regional Analysis
- 1, 5 - Natural Resource Economics

Forest Service - Research (FS)

Farmer Cooperative Service (FCS)

- 4, 5 -

Statistical Reporting Service (SRS)

- 4, 5 -

SUBJECT MATTER PROGRESS REPORTS

- 6 - Forestry (other than Forest Service)
- 7 - Animal-Poultry and Products Research Other Than Husbandry, Disease and Parasite
- 8 - Cotton and Cottonseed
- 9 - Grain and Forage Crops
- 10 - Horticultural Crops
- 11 - Oilseed and Peanut Crops
- 13 - Sugar Crops
- 14 - Tobacco

A copy of any of the reports may be requested from Max Hinds, Executive Secretary, Sugar Crops Research Advisory Committee, Research Program Development and Evaluation Staff, U. S. Department of Agriculture, Washington, D. C. 20250

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INTRODUCTION

This report, which is prepared annually, deals with work directly related to the production, processing, distribution, and consumption of sugarcane, sugarbeets, and sweet sorghum. It does not include extensive cross commodity work, much of which is basic in character, which contributes to the solution of not only sugar problems but also to the problems of other commodities. Progress on cross commodity work is found in the organizational unit reports of the several divisions.

The report covers Farm Research; Nutrition, Consumer and Industrial Use Research; and Economic Research. As shown in the table of contents, there is a breakdown of the research program by problem areas.

For each subject matter area there is a statement of the problem, USDA and cooperative program, information about the program at State Experiment Stations, if available, a summary of progress during the past year on USDA and cooperative programs and a list of publications including state work where this information is available.

Research on sugar crops is supported by (1) Federal funds appropriated to the research agencies of the U. S. Department of Agriculture, (2) Federal and state funds appropriated to State Agricultural Experiment Stations, and (3) private funds allotted, largely by sugar industries, to research carried on in private laboratories or to support of State Station or USDA work.

Research by USDA

Farm Research in the Agricultural Research Service comprises investigation on introduction, breeding, and genetics, variety evaluation, culture, diseases, nematodes, weed control, insects, and crop harvesting and handling operations and equipment. It is carried out in the following divisions: Crops, Entomology, and Agricultural Engineering. The work involves 69 professional man-years of scientific effort.

Nutrition, Consumer and Industrial Use Research conducted in the Agricultural Research Service discussed in this report pertains to the chemical and physical properties, new and improved products, new and improved processing technology of sugar crops. The research was conducted by the following divisions: Southern Utilization Research and Development Division, Consumer and Food Economics, and the Human Nutrition Divisions. The work on sugarbeets at the Western Utilization Research and Development Division and work on sugarcane at both the Northern and Southern Utilization Research and Development Divisions was terminated at the close of the 1965 fiscal year. Publications pertaining to sugarbeet research conducted prior to termination of the program at the Western Utilization Research Laboratory are included in this report. The continuing research effort involves 2 professional man-years.

Economic Research pertains to the organization and performance of markets with respect to market institutions and market power; prices, margins, and costs; and location and interregional competition. This work is conducted by the Marketing Economics Division of the Economic Research Service. Research in cooperative marketing is conducted by the Farmer Cooperative Service. The sugar research in these Services involves 2 professional man-years.

Interrelationships Among Department, State and Private Research

A large part of the Department's research is cooperative with State Experiment Stations. Many Department employees are located at State Stations and use laboratory and office space close to or furnished by the station. Cooperative work is jointly planned, frequently with the representatives of the producers or industry participating. The nature of cooperation varies with each study. It is developed so as to fully utilize the personnel and other resources of the cooperators, which frequently includes resources contributed by the interested producers or industry.

Research by industry and other organizations is sponsored primarily by beet and sugarcane companies, processors, sugar refiners, and chemical companies.

Beet sugar companies conduct applied research on breeding and genetics, nutrition, and agronomic practices, including production and processing of sugarbeet seed. The Department supplies new varieties and conducts the basic research needed by the beet sugar companies in their research program.

Large companies that grow sugarcane in Florida, Louisiana, Puerto Rico, and Hawaii conduct research on breeding, variety evaluation, cultural practices, fertilization, and the use of chemicals to expedite (1) the accumulation of sugar in sugarcane, and (2) harvesting operations. Information from such research is made available to Federal and State scientists who cooperate by conducting the basic research necessary to such activity.

Chemical companies conduct research for the development of more effective fungicides for the control of diseases which attack sugar crops and for side dressings. Also, some chemical companies are engaged in the formulation of chemicals for use as desiccants, as fungicides, as growth stimulants, and as retardants to hasten maturity of sugarcane. Federal and State groups provide the basic and fundamental phases essential to this area of research.

Basic research done by the Department and States will be utilized by industry and other organizations in their research programs, especially in the further development of improved products and equipment. Industry's cooperation in supporting sugar research at Federal and State Stations has contributed greatly to its success.

Example of Recent Research Accomplishment by USDA and Cooperating Scientists

Four New Varieties of Sugarcane Released to U. S. Growers. Four new varieties of sugarcane became available to sugarcane growers in the fall of 1967. Three of these, CP 56-59, CP 57-603, and CP 59-73, are recommended for culture in Florida, and one, CP 61-37, for Louisiana. The new varieties are superior to available commercial varieties in yields of sugar per acre, in stubbling capacity, and in disease resistance. Erect growth under favorable conditions, shedding of lower leaves near maturity, and freedom from brittleness favor mechanical harvesting of CP 56-59, CP 59-73, and CP 61-37; CP 57-603 can also be harvested mechanically under some conditions.

I. FARM RESEARCH

SUGAR PLANT BREEDING AND GENETICS, DISEASES, QUALITY AND VARIETY EVALUATION, CULTURE, AND PHYSIOLOGY

Crops Research Division, ARS

Problem. Labor requirements for sugar production should be reduced through the development of varieties of sugar crops that will facilitate mechanization of field practices. Basic genetic research should be strengthened with special emphasis on mode of inheritance of chemical constituents and resistance to pathogens, insects, and environmental stress. Fundamental principles should be developed to provide concomitant improvement in quality and in acreable yield of raw products.

Diseases of sugar crops, especially virus yellows of sugarbeet and ratoon stunting of sugarcane, affect quality and reduce yield. New strains of the curly top virus of sugarbeet and of the mosaic virus of sugarcane are capable of severely damaging varieties that are tolerant to strains formerly prevalent in a region. Soil-inhabiting pathogens attack the root systems of sugarbeet and of sugarcane, inflicting heavy losses, and the microbial flora of the rhizosphere may have a bearing on unthrifty growth of sugar crops and on the failure of sugarcane plantings to endure repeated harvest and regrowth.

PROGRAM--USDA AND COOPERATIVE PROGRAMS

The Department has a continuing program of basic and applied research in the disciplines of breeding, genetics, pathology, physiology, biochemistry, and botany, which is directed to the solution of problems of sugar production. In addition to research at Beltsville, Md., and at Federal Field Stations in Calif., Fla., Ga., La., and Miss., investigations are conducted cooperatively with State Experiment Stations on sugarbeet in Ariz., Calif., Colo., Maine, Mich., Minn., N.Y., and Utah; and on sugarcane and sweet sorghum in Ala., Fla., Ga., Ky., La., Miss., Tenn., Texas, South Carolina, and Puerto Rico.

Cooperative sugarbeet research is strengthened at Salinas, Calif., Fort Collins, Colo., Beltsville, Md., and Logan, Utah, through funds contributed by the Beet Sugar Development Foundation; at Beltsville, Md. and East Lansing, Mich., through funds contributed by the Farmers and Manufacturers Beet Sugar Association; and at Salinas, Calif. through funds contributed by the Union Sugar Division, Consolidated Foods Corporation, and by the California Beet Growers Association. Research on sugarcane and sweet sorghum is carried out in cooperation with the American Sugar Cane League in La., and Fla., and with the Cairo Cane Growers' League in Ga., with the Florida Sugarcane League in Fla., with the Hawaiian Sugar Planters' Association in Hawaii, and in Puerto Rico on funds contributed by the Association of Sugar Producers of Puerto Rico.

There are 12 extramural projects pertaining to sugarbeet research: Summer and winter cropping in sugarbeet, Arizona Agricultural Experiment Station, Tucson, Ariz.; Breeding sugarbeet for Northeastern States, Cornell Agricultural Experiment Station, Ithaca, N. Y.; Physiological effects of virus yellows on sugarbeet, California Agricultural Experiment Station, Davis, Calif.; Chemical constituents influencing quality of sugarbeet, Colorado Agricultural Experiment Station, Fort Collins, Colo.; Raffinose formation and decomposition in sugarbeet, Utah Agricultural Experiment Station, Logan, Utah; Influence of acid soils on nutrition and growth of sugarbeet, Maine Agricultural Experiment Station, Orono, Maine; Quantitative growth of the sugarbeet, Colorado Agricultural Experiment Station, Fort Collins, Colo.; Effects of cultural practices and variety on keeping quality of sugarbeet, Michigan Agricultural Experiment Station, East Lansing, Mich.; Development of sugarbeet germ plasm that is resistant to virus yellows and the aphid vector, Washington Agricultural Experiment Station, Prosser, Wash.; The biochemical nature of resistance to Cercospora leaf spot, Colorado Agricultural Experiment Station, Fort Collins, Colo.; Production practices and storage environment in relation to keeping quality of beets, Utah Agricultural Experiment Station, Logan, Utah; and Selecting and breeding in Chile for yellow wilt resistance, Beet Sugar Development Foundation, Fort Collins, Colo. Three extramural projects pertain to sugarcane research: Physiological and biochemical studies on yield decline in sugarcane, Experiment Station, Hawaiian Sugar Planters' Association, Honolulu, Hawaii; Acceleration of yield decline in sugarcane through application of stress, Experiment Station, Hawaiian Sugar Planters' Association, Honolulu, Hawaii; and Factors influencing decline in yield of varieties, Agricultural Experiment Station, University of Puerto Rico, Rio Piedras, Puerto Rico.

Under Public Law 480 grants, research is conducted on Cercospora leaf spot of sugarbeet in Israel and on interspecific hybrids of the genus Beta in Poland. In India, research is being conducted on virus diseases of sugarcane and on hybridization of parental varieties from Florida, Puerto Rico, and Hawaii with Saccharum spontaneum and other species to develop cold-, disease-, drought-, and pest-resistant germ plasm suitable to evolve superior commercial varieties for the U. S. mainland, Puerto Rico, and Hawaii.

The Federal Intramural Program of research on sugar crops comprises a total of 52.0 scientist man-years allocated as follows: 19.9 to breeding and genetics; 13.7 to diseases, 8.8 to quality and variety evaluations; and 9.6 to physiology and culture. These man-years are distributed for crops as follows: sugarbeet - 10.2 to breeding and genetics, 7.2 to diseases, 5.3 to quality and variety evaluation, and 4.3 to physiology and culture; sugarcane and sweet sorghum - 9.7 to breeding and genetics, 6.5 to diseases, 3.5 to quality and variety evaluation, and 5.3 to physiology and culture.

The Extramural Program of projects under contract and cooperative agreement totals 5.3 SMY (3.8-sugarbeet and 1.5-sugarcane and sweet sorghum) allocated as follows: sugarbeet - 1.2 to genetics and breeding, 0.8 to diseases, 0.7 to quality and variety evaluation, and 1.1 to physiology and culture; sugarcane and sweet sorghum - 1.5 to physiology and culture.

PROGRAMS OF STATE EXPERIMENT STATIONS

The research effort of the State experiment stations in this area totals 48.5 scientist man years.

PROGRESS--USDA AND COOPERATIVE PROGRAMS

A. Breeding and Genetics

1. Sugarbeet

a. Yellows Resistant Hybrids. Several successive generations of selecting have provided C413 which is resistant to yellowing viruses of sugarbeet and moderately resistant to bolting. When C413 was used as pollen parent, experimental hybrids gave excellent performance in several sugarbeet districts of California where virus yellows is a serious disease. The most productive of the experimental hybrids is being officially released for commercial use as US H9. This is the first yellows resistant variety of sugarbeet for this country. Although the pollen parent is multigerm, the seed parent is monogerm; therefore, the commercial hybrid seed will be monogerm.

b. Male Sterility Facilitates Hybrid Seed Production. The irregular performance of cytoplasmic male sterility prevents the use of many lines of sugarbeet in hybrid seed production. Current research tends to confirm F. V. Owen's original postulate that the character is conditioned by the interaction of Mendelian genes and cytoplasmic factors. The latter are not clearly understood. The matroclinous inheritance of male sterility simulates the transmission of a pollen inhibiting virus. Extensive trials failed to demonstrate that the cytoplasmic entities pass through a graft. Sugarbeet viruses, however, are readily transmitted through such unions. The utilization of cytoplasmic male sterility has advanced through the discovery of certain lines that fully restore the pollen production in the progeny of cytoplasmically male-sterile sugarbeet. This discovery makes feasible the commercial production of double cross seed. Broader parentage should provide wider adaptation of hybrids and enhance sugar production.

c. Combining Disease Resistance. The facility with which combinations of important characteristics are imparted to hybrids through interchange of parental lines is utilized in the establishment of multiple resistance in sugarbeet varieties. For example, through choice of a complementary pollinator, an F_1 hybrid that is resistant to curly top and bolting becomes a 3-way hybrid with added yellows resistance; whereas with another pollinator, an F_1 that is resistant to leaf spot produces a 3-way hybrid with added curly top resistance. In regional field trials, these 3-way hybrids have been outstanding in productivity, due largely to multiple disease resistance. The development of basic parental lines is being emphasized at four centers of sugarbeet research.

d. New Germ Plasm. Progress is being made in utilization of the great wealth of germ plasm available in wild species of Beta. The current program pertains largely to the F_2, b_1, and b_2 generations from several original interspecific hybridizations. In hybridizations of sugarbeet and Beta corolliflora, 29 plants in one b_1 progeny remained symptomless after the second inoculation with a severe strain of the curly top virus. In F_2 progeny of sugarbeet x B. patellaris, 6 plants remained free of encysted nematodes (Heterodera schachtii) after the third inoculation. Immunity to curly top or to the cyst nematode has not be observed in cultivars of sugarbeet, but does occur in wild species of Beta. The breeding research on interspecific hybrids offers a new level of protection against these serious pests.

2. Sugarcane

Varieties of sugarcane having high sugar content, resistance to diseases and insects and to cold damage, and adapted for mechanical harvesting are developed through breeding research at Canal Point, Fla., Cairo, Ga., Houma, La., and Meridian, Miss. In the 1966-67 crossing season, 263 crosses made at Canal Point provided approximately 1,536,714 viable seed to produce more than 450,000 seedlings for field evaluation in Florida, Louisiana, and the sirup-producing areas. Approximately 50% of the seedlings in Louisiana were discarded because of susceptibility to mosaic.

a. Germ Plasm. Research at Beltsville, Canal Point, and Houma to develop new germ plasm for the breeding program provided more than 50,000 seedlings during 1966 from interspecific and intergeneric crosses for evaluation under greenhouse and field conditions. The crosses involved four genera closely related to sugarcane and three species of Saccharum. A new technique for crossing diverse types of sugarcane as female parents and multiple males of related genera may increase efficiency of the intergeneric crossing work. Approximately 21,000 seedlings from interspecific crosses made in India under P.L. 480 project A7-CR-1 were screened for mosaic susceptibility at Houma, La., and Beltsville, Md. Approximately 220 of these seedlings, apparently resistant to mosaic, were transplanted for field evaluation at Houma in the spring of 1967.

b. Selections. Approximately 20,000 sugarcane seedlings were selected in Florida, Georgia, Louisiana and Mississippi during 1966 for further, more critical evaluation. Some of the selection work in Louisiana was hindered by severe freeze damage on November 3. Evaluation of promising selections under a range of environmental conditions was in cooperation with Agricultural Experiment Stations in Florida, Georiga, Louisiana, Mississippi, and Puerto Rico, and the American Sugarcane League, the Cairo Cane Growers' League, the Florida Sugarcane League, and the Association of Sugar Producers' of Puerto Rico.

c. Crossing Techniques. A series of photoperiod treatments at Canal Point that involved nine different arrangements of 11.5-hour dark periods daily from September 13 to October 25 resulted in significant delay in flowering of some varieties. The maximum delay in flowering was eleven weeks; during that period flowers were available for many crosses heretofore considered impossible at Canal Point. This new development increases greatly the potential for making a wide range of sugarcane crosses at Canal Point.

d. Genetic Studies. Investigations carried out at Houma to study the inheritance of resistance to red rot involved four crosses. Studies were also carried out to determine hhe inheritance of components of yield including stalk number, stalk diameter, stalk height, stalk weight, Brix and sucrose. In connection with this study, investigations were carried out to determine the inheritance of hardness of the rind and resistance to borers.

e. World Collection. The World Collection of five species of Saccharum, special hybrids, and related grasses comprises approximately 1,500 clones of valuable germ plasm. Approximately 150 additional clones were imported during 1966. Studies were carried out at Canal Point to determine the time of flowering of the different clones. Investigations of validity of clonal names were continued throughout the year.

3. Sweet Sorghum

Varieties of sweet sorghum, superior in yielding ability, quality of juice for sirup production, and resistance to diseases are developed by breeding at Brawley, Calif., Cairo, Ga., Beltsville, Md. and Meridian, Miss.

a. Isogenic Lines. Evaluation of isogenic lines of the sweet sorghum variety, Tracy, were continued at Meridian in 1966. Tracy plants, resistant to infection by Colletotrichum graminicolum, were selfed to produce seed for backcross studies in 1967.

b. Genetic Studies. Evaluation of the progeny of a cross between two varieties, Williams and Sart, at Blairsville, Ga., furnished additional information about the inheritance of plant characters. In this study, maturity was controlled by a single-factor pair. Seedling color was inherited independently of maturity and controlled by a single-factor pair of genes with the red color dominant over the green. Leaf anthracnose susceptibility was controlled by two-factor pairs, and these genetic factors were dependent on the factor pairs controlling maturity and seedling color. There was a negative correlation between seed weight and Brix in early and late maturing plants of the progeny. In general, early maturing lines had a lower juice extraction, a lower Brix, and greater seed weight.

c. Hybrid Varieties. Investigations were continued at Meridian to evaluate the potential of hybrid varieties for growth capacity and juice quality. There are indications that crosses of varieties that produce high yields do not exhibit hybrid vigor in height or stalk weight. When one of the parent varieties in the cross has anthracnose resistance, the hybrid variety will also have resistance. There is no evidence of true hybrid vigor for juice quality. Hybrid varieties from high quality disease-resistant parents have a tendency to be inferior to the parents in quality of juice as determined by Brix, sucrose, and purity.

d. World Collection. Approximately 300 varieties of the World Collection were subjected to severe inoculation tests at Beltsville, Md., during 1966 to evaluate them for resistance to red rot (Colletotrichum graminicolum), zonate leaf spot (Gloecercospora sorghi), and bacterial stripe (Pseudomonas andropogoni). Varieties resistant to the three diseases were selected for further study and for use in hybridization. Data about productive capacity, sugar content, and relative adaptability to abnormal seasonal conditions were also obtained from the study.

B. Diseases

1. Sugarbeet

a. Root Rot Resistance. Selecting for resistance to Rhizoctonia solani has given rise to lines of sugarbeet with a new level of tolerance to this ubiquitous pathogen. In these lines, resistance tends to increase with age of plants, which is fortunate because the greatest losses from Rhizoctonia rot usually occur in midsummer or later in the growing season. Resistance to postharvest rot of beets has antecedents in field practices and variety. Furthermore, changes occurring during storage tend to make beets more susceptible to spoilage. A laboratory technique used to appraise tolerance to rot induced by Botrytis cinerea determined that low nitrogen nutrition predisposes beets to this pathogen. This technique is being used in breeding basic parental lines for resistance to postharvest spoilage.

b. Nematode Resistance. Progress has been achieved in separating the effects of fungous and nematode pathogens in the disease complex. This significant accomplishment has revealed that resistance to the complex inoculum is strikingly different from resistance to nematode inoculum. Previous accomplishments in breeding for tolerance to the nematode disease complex can be attributed to the establishment of resistance to the fungous pathogens more than to protection against the cyst nematode.

c. Remote Sensing of Sugarbeet Leaf Spot. Annual surveys are made to follow development of the leaf spot disease and to provide information for determining the need of fungicidal treatment for control. The survey covered about 100 fields in sugarbeet districts of Minnesota-North Dakota. When conducted from the ground, each of the 3 annual surveys require about 7 days. Through cooperation with the University of Minnesota, a commerical aerial photographer made three flights over an experimental field in which leaf spot was encouraged. They determined that 1,000 feet was the most feasible altitude for photographing disease details. At the time of the July 15 flight, there was little disease, and none was discernible in the photographs. On August 15, the disease had reached medium intensity and was detectable on plants in all plots. The healthy plants were a bright cherry red in the photograph; but the diseased plants tended to be chocolate brown--the greater the disease, the darker the color. This preliminary test indicates the possibility of making disease surveys by aerial sensing from plane flights.

2. Sugarcane

The two most important diseases of sugarcane in Florida and Louisiana are mosaic and the ratoon stunting disease. Both diseases, caused by viruses, can cause significant losses in yield. Most of the current pathological research relates to these two diseases.

a. Mosaic: In Louisiana losses from mosaic were closely related to varieties. Levels of infection that caused significant losses in L. 60-25 caused no significant losses in C.P. 52-68. Losses are related to the percent of plants infected. Varietal resistance is the only real control for the mosaic disease. Heat treatment of seedcane adequate for control of the ratoon stunting disease did not influence movement of the mosaic virus within the seed piece. There are indications that carefully controlled heat treatment may in some cases effect a cure of the mosaic disease. Further studies are needed to prove validity of these data. Two collections of mosaic in 1966 may represent new strains of the virus. Symptoms caused by the two collections were severe, and they were easily transmitted to sugarcane and to sweet sorghum. One of the collections was obtained from johnsongrass. This indicates the possible role of johnsongrass as a source of the mosaic virus for infection of sugarcane plants. In Florida, the strain of mosaic that normally infests St. Augustine grass was found to be the one prevalent in varieties of the

World Collection at Canal Point. Some progress was made in developing a local lesion host for identification of the St. Augustine grass strain of the virus. A reliable development of local lesion symptoms is influenced by environmental conditions. Sugarcane plants have the capacity to recover from the St. Augustine grass strain of mosaic. Data available now indicate that recovery is of the "virus-free" type and not a mere masking of symptoms. Research is in progress to develop an assay technique for the sugarcane mosaic virus. A mechanical planter has been developed that permits rapid planting of large numbers of spaced test plants of sweet sorghum. The spaced plants can be spray inoculated, as they are conveyed at a constant speed on an endless belt past the spray gun. This procedure may greatly increase the efficiency of testing for the presence of the mosaic virus.

b. Ratoon Stunting Disease. In Louisiana, the effect of ratoon stunting disease (RSD) is most pronounced in reduction of yield of cane. Successive heat treatments of cane indicate that the second cycle of treatments had a beneficial effect on germination and growth of the cane. Further data are needed to measure with certainty the effect on yield, especially in stubble crops. Some progress was made in developing an antiserum for the ratoon stunting disease virus at Houma. In density-gradient studies with infected C.P. 44-101, most of the infective RSD virus was in the 1.3 cm band. Concentration of the virus in this small band near top of the density-gradient tube is an asset in developing serological techniques for studying the virus.

c. Soil Organisms. Data were obtained in Puerto Rico about the fungi present in the root zone area of sugarcane. Several genera of fungi were isolated; these included Curvularia, Fusarium, Pythium, and Rhizoctonia. Pythium is one of the major growth-retarding organisms in the rhizosphere. Investigations are in progress to determine the pathogenicity of the fungal isolates collected during 1966. It is necessary in some cases to develop new techniques for evaluating the importance of these pathogens. It is apparent by the effect on growth of sugarcane seedlings that some isolates of Pythium are much more virulent than others. It was possible to reisolate the Pythium fungus from seedlings that showed severe wilting and death from the effect of the organism. The studies will be used to confirm differences in degree of virulence of isolates of the pathogen.

d. Leaf Scald. Further investigations were carried out in 1966 to evaluate the effect of isolates of leaf scald (Xanthomonas albilineans) isolated in Puerto Rico in 1965. Two varieties, B.H. 10/12 and Co. 281, were inoculated with aqueous suspensions of the isolates. All isolates were pathogenic to the host varieties. Co. 281 was less susceptible than B.H. 10/12 to all of the isolates. Symptoms of the disease were expressed best on 4- to 5-month-old primary shoots of the two varieties.

3. Sweet Sorghum

Two new diseases of sweet sorghum tentatively classified as "mosaic" and "stunt" were identified during 1966. Data collected during the spring of 1967 indicate that these diseases may be wide spread throughout the Southern States. Varieties differ in susceptibility to these diseases.

a. "Mosaic". A "mosaic" disease of sweet sorghum was observed at five locations during 1966, Blairsville, Ga., Quicksand, Ky., State College and Pontotoc, Miss., and Castorville, Texas. The disease was since been observed in other locations. There are two principal types of symptoms: (1) a yellow-green mosaic pattern on the whorl leaves typical of sugarcane mosaic, and (2) a brilliant red mottled streaking of the whorl leaves, Mosaic symptoms similar to those observed on sweet sorghum were also found at Blairsville, Ga., on sweet corn, johnsongrass, and other crop plants. The mosaic disease was readily transmitted mechanically, and by aphid vectors, Rhopalosiphon maydis and Dactinotus ambrosiae.

b. "Stunt" Disease. Another new disease that caused stunting of sweet sorghum was observed at Fairhope, Ala., Blairsville, Ga., Quicksand, Ky., and Meridian and State College, Miss. Infected plants were approximately half as tall as normal plants. Leaves of infected plants were bunched together at the upper part of the stalk. This condition tentatively designated "stunt" did not resemble mosaic. Individual plants were found in plots with no identifiable spread pattern. Research is in progress to determine if the condition can be transmitted by insects.

c. Disease Survey. Pathological observations in variety tests and field plantings of sweet sorghum throughout Alabama, Georgia, Kentucky, Louisiana, Mississippi, South Carolina, and Texas indicate that red rot (Collectotrichum graminicolum) and zonate leaf spot (Gloeocercospora sorghi) are wide spread. Bacterial stripe (Pseudomonas andropogoni) is prevalent under some conditions. In Texas, severe damage was caused by insecticide sprays; the effect of insecticides varies with varieties.

C. Quality and Varietal Evaluation

1. Sugarbeet

a. Varietal Storage Quality. Sulfur, potassium, and alpha amino acids remain rather constant in the beet during storage, and sucrose losses are manifested by the evolution of carbon dioxide. Thus, after a period of storage, any additional impurities not attributed to these constituents probably arise from the degradation of marc material in the beet. Differences in marc stability or in its proclivity to degradation have been found among varieties of sugarbeet.

b. Polyploidy. Cooperative field trials with experimental polyploid hybrids have not given performances superior to those of related diploid hybrids. Poor quality of seed, probably due to ineffectiveness of tetraploids as pollinators, is a depreciating characteristic of polyploid hybrids. The ease with which the sugarbeet can be autotetraploidized with colchicine had facilitated programs of interspecific hybridization.

2. Sugarcane

Varieties of sugarcane developed in the breeding program at Canal Point, Fla., are evaluated for yield, sugar content, and disease- and cold-resistance in cooperation with agricultural experiment stations in Louisiana, Florida, Mississippi, Alabama, and Puerto Rico, the American Sugarcane League, the Florida Sugarcane League, the Cairo Cane Growers' League, and the Association of Sugar Producers of Puerto Rico. In 1966, varietal evaluation under more than a dozen soil and growth conditions indicated the superiority of three varieties in Louisiana, C.P 61-37, L. 61-43, and L. 61-67, and three in Florida, C.P. 56-59, C.P. 57-603, and C.P. 59-73. In addition, two varieties, C.P. 62-374 and C.P. 63-588, have given promising results in limited field experiments in Florida; further experiments in stubble crops are needed for more precise evaluation of these varieties.

a. New Varieties. Data from field experiments in Louisiana show that C.P. 61-37 is superior to current commercial varieties in yielding capacity, disease resistance, and adaptability for mechanical harvesting. This variety was recommended in July 1967 for release to growers for commercial culture. Data from field experiments in Florida show that three varieties, C.P. 56-59, C.P. 57-603, and C.P. 59-73, are superior to current commercial varieties under a range of conditions in that area. Two of these varieties, C.P. 56-59 and C.P. 59-73, are especially adapted for cold-land areas of the State, and C.P. 57-603 for warm-land areas near Lake Okeechobee. The three varieties were recommended in July 1967 for release to growers for commercial culture. L. 60-25 released for commercial culture in Louisiana in May 1966 continues to give good results under a wide range of conditions in that State. It produced yields significantly higher than those from C.P. 52-68, the leading commercial variety. The new variety U.S. 59-16-1 released in Florida in 1965 produced yields of cane approximately equal to those from Cl. 41-223. Data from all field experiments show that the new variety exceeded Cl. 41-223 by 15% in yield of sugar per acre.

b. Cold-Resistant Varieties. In Louisiana freezing temperatures of 24°F on November 3 provided an opportunity for studying cold resistance of 15 commercial and unreleased varieties. Quality of the cane was still acceptable for milling three months after the freeze. This favorable response indicates progress in developing cold-resistant varieties of

sugarcane. Representative varieties of five species of Saccharum were subjected to freeze damage at 27°F in Louisiana. Varieties of S. spontaneum and S. sinense and interspecific hybrids showed the greatest cold tolerance. The most outstanding variety for resistance to frost was C.P. 57-526. Limited tests indicate the possibility of developing a technique for evaluating young seedlings for cold resistance. Further studies are needed to perfect the technique. Special techniques were investigated for evaluating cold damage of mill cane on the basis of tissue deterioration. These studies show that stalk damage depends on the interaction of temperature and time. The most resistant variety in this study was C.P. 61-37. In Mississippi, sugarcane seedlings were subjected to freezing temperatures of 26° to 32°F for 5, 6, 7, or 8 hours. The length of time in the freezer room influenced the number of seedlings frozen to the soil level. Limited data indicate that seedlings from different crosses vary in cold resistance. This finding indicates the potential for selecting cold-resistant lines through breeding. Studies of hybrids between commercial parents and S. spontaneum show that some of the clones had high cold resistance. Further studies are in progress to improve techniques for cold-resistant treatments and also for evaluating the results.

3. Sweet Sorghum

Sweet sorghum varieties developed in breeding programs at Beltsville, Md., and Meridian, Miss., are evaluated in cooperation with Agricultural Experiment Stations in Ala., Ga., Ky., La., Miss., South Carolina, Tenn., and Texas. New varieties are evaluated in the eight States on more than 20 soil types under a wide range of growth conditions for sirup and sugar production; they are also evaluated under irrigated conditions in the Imperial Valley of California.

a. New Varieties. Data from 20 regional experiments show that three varieties, Mer. 59-1, Mer. 64-6, and Mer. 64-12 are superior in several characteristics for sirup production. Mer. 59-1 produces an exceptionally good-quality sirup and it also resists lodging. The seed supply of this variety is being increased for possible release in the spring of 1968. Mer. 64-6 is very similar to Wiley in maturity and yielding capacity; it is superior to Wiley in resistance to lodging. Another variety, Mer. 64-12, that matures about the time of Tracy, is resistant to leaf anthracnose and has less starch in the juice than Tracy which results in a better quality sirup. The two varieties, Mer. 64-4 and Mer. 64-12, are potential candidates for commercial culture following additional testing.

D. Culture and Physiology

1. Sugarbeet

a. Physiology of Virus Infection. Necrosis is seldom a primary symptom of virus infection in sugarbeet, nevertheless, viruses are strong inhibitors of growth. Studies have been made on various stages of curly top infection. The net accumulation of material, which represents the difference between synthesis by photosynthesis and destruction by respiration, showed a rate of decline, with infection, at both high light intensity and low CO_2 and at low light intensity and high CO_2. The rate of decline was more rapid for the first three weeks after infection when measured under low light intensity and high CO_2 concentration. Research has demonstrated that nitrogen nutrition and plant genotype can effect the changes in sucrose percentage of yellows infected plants. The results suggest that certain genotypes exhibit tolerance to the virus only when nitrogen deficiencies develop during growth.

b. Nature of Leaf Spot Resistance. The occurrence of a phenolic compound identified as 3-hydroxytyramine, which is toxic to Cercospora beticola, has been found in leaves of sugarbeet. Association of Cercospora leaf spot resistance and the concentration of the compound is being investigated to determine the biochemical nature of resistance. Studies on chemical genetics of the compound indicate that simultaneous improvement can be more easily achieved in sucrose percentage and 3-hydroxytyramine or in beet weight and the compound than in sucrose percentage and beet weight combined. Young leaves contain more 3-hydroxytyramine than the older leaves. Leaf injury increased the concentration of the phenolic compound. Resistance to the pathogen may depend on the ability of a plant to synthesize the toxic substance in response to injury more than on naturally occurring concentration of the compound in leaves.

c. Field Practices. In Arizona, beet yields on 40-inch double row beds were significantly greater than yields on 24- and 30-inch single row beds. Beets from the double row bed culture were best in quality. All row widths with 10-inch spacing along the row gave the best beet yields. Increasing applications of nitrogen enhanced beet yield, but resulted in concomitant reduction in sucrose percentage. In Colorado, heavy applications of nitrogen in the row interfered with seed germination. Preplant applications of nitrogen were superior to side-dress applications. In quantitative growth studies, leaf area index was influenced by nitrogen application. Sugarbeets grown in Caribou (Maine) soil, pH 4.2, produced small, unthrifty plants; but large, robust plants resulted from lime applications that changed the soil reaction to pH 5.7.

2. Sugarcane

a. Culture. In Louisiana, there was no difference in yield of cane when the crop was cultivated one or three times, where weeds were controlled with herbicides. In other experiments, herbicides reduced the yield of

some varieties. The yield of C.P. 52-68 was reduced by herbicides. Herbicides apparently damaged roots of the plants. There was a significant interaction between varieties and herbicides. Varieties differ in their response to time of planting. When the seedcane was planted August 15, C.P. 44-101, C.P. 52-68, and L. 60-25 produced more cane per acre than similar plantings in September and October. September was the best time to plant C.P. 48-103, and C.P. 55-30. Further study is needed to determine with precision the best time to plant each variety.

b. Fertilization. Data from 18 experiments in Louisiana during the period 1957-1966 show a significant increase in yield of cane and sugar per acre from 80 lbs. of nitrogen as compared to 40 lbs. The small reduction in sucrose (.07%) was not significant. There was also a significant increase in yield from 120 lbs. of nitrogen as compared to 80 lbs.; however, the high rate of nitrogen caused a significant decrease in the percentage of sucrose. In Louisiana the addition of 40 lbs. of phosphate and 80 lbs. of potash, plus nitrogen, increased yields significantly, 2.35 tons of cane and 355 lbs. of sugar per acre, as compared to nitrogen alone.

c. Flowering. In Hawaii, night light interruption delayed flowering of some varieties 4 to 6 weeks. The same treatment prevented tasseling of other varieties. Low night temperatures after differentiation delayed the flowering of some varieties of sugarcane as long as 2 months. Delay in flowering of many varieties helps to synchronize flowering of desirable parental clones.

d. Dark Carbon Dioxide Fixation. Data from flowering experiments in Hawaii show that 63% of the CO_2 is fixed by the midpoint of the dark period. Low intensity light applied to leaves at midpoint of the dark period did not affect the total dark fixation of CO_2. Further studies are in progress to measure with accuracy the relation of CO_2 fixation to the flowering process.

e. Tissue Cultures. Basic studies in Hawaii, utilizing tissue cultures of sugarcane under laboratory conditions, indicate this as an important tool for studying environmental stress conditions. When vegetative materials from tissue cultures are transplanted to normal growing conditions, they are first abnormal in growth, but later regain their original productive capacity and successive generations under field conditions show no reductions in yield.

f. Plant Excretions. Data from basic studies in Hawaii show that several phytotoxic substances have been separated from extracts of sugarcane roots. Techniques have been developed to measure phytotoxicity of the root extracts. Data now available indicate that there are several

types of phytotoxic substances in sugarcane roots, that these differ in stability and solubility, and that toxicity varies with varieties. Further studies are in progress to determine the role of these phytotoxic substances on the rhizosphere complex, and on the decline in yield of sugarcane.

3. Sweet Sorghum

a. Dates of Planting. In Mississippi, sweet sorghum planted in May and June produced higher yields of stalks per acre than plantings in April. There was no significant difference in quality of juice from any of the dates of plantings. Sweet sorghum can be planted safely in Mississippi during the period May 1 to June 15.

b. Harvesting. In Mississippi, maximum yields of sweet sorghum were obtained when the crop was harvested in the ripe stage of maturity. High juice quality continued approximately 4 weeks after the ripe stage. There was a small decrease in juice quality 4 weeks after the ripe stage, based on Brix.

c. Freeze Damage. A temperature of 18°F at Meridian on November 3, and freezing temperatures on the three following nights had no significant influence on the quality of juice from sweet sorghum 4 days later. Decrease in quality 11 days after the freeze was significant, and by 18 days, the sucrose content was too low for measurement. It is apparent that sweet sorghum must be harvested within 4 to 8 days after a severe freeze to avoid significant losses.

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WEED AND NEMATODE CONTROL
Crops Research Division, ARS

Problem. In spite of the best efforts to control weeds they still constitute one of the major items in the production costs in food, feed, and fiber crops. Many pest problems are interrelated. In the development of future weed, insect, disease, and nematode control measures involving pesticides and herbicides, more attention must be given to principles of application that avoid or minimize residues. There is the possibility of carryover of pesticides in the soil which may damage or cause undesirable residues in succeeding crops.

Weeds harbor insects that attack crops or transmit diseases to crops, and serve as alternate hosts of disease organisms and nematodes. Successful mechanization of the sugarbeet crop is impossible until some effective control is obtained on both broadleaf weeds and grasses. Grass eradication in sugarcane continues to be the major weed control problem due to the susceptibility of sugarcane to damage from herbicides effective on grasses.

In sugar crops the extent of damage by nematodes is not known except that serious economic losses occur. Studies are needed on nematodes in sugar crops to determine the extent of damage and their relationship to soil pathogens and modes of control. Chemical control offers the best means of controlling these destructive nematodes. Low-cost effective methods of controlling nematodes with nematocides need to be developed. Chemical control studies are needed as part of an interdisciplinary approach to integrated control of nematodes, weeds, pathogenic soil fungi, and insects, supported by competent agricultural engineering know-how.

USDA AND COOPERATIVE PROGRAM

Much of the weed control research in the Department is cooperative with State Experiment Stations, other Federal agencies, industry, and certain private groups. The work is cross commodity in nature. The weed control program involves 3.0 scientist man-years devoted to sugar crops, all intramural. The work locations are Tempe, Arizona; Fort Collins, Colorado; Houma, Louisiana; St. Paul, Minnesota; and Prosser, Washington.

The Federal scientific effort devoted to nematode research on sugar crops amounts to 2.4 SMY's, with the work located in California and Louisiana.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Weed Investigations

1. Sugarbeet-Kochia Competition. In Colorado, sugarbeets yielded normally if protected from competition of kochia and other weeds for the first four weeks after planting. Likewise normal yields were made if all weeds were removed within five weeks after planting. Root yields and gross sucrose were decreased, however, if kochia was allowed to compete for longer than five weeks after planting.

2. Control of Weeds in Sugarbeets. In Colorado, the best selective control of weeds in sugarbeets was provided by a combination including a preplanting mixture of R2063 and pyrazon followed by a postemergence mixture of pyrazon and dalapon. The weeds kochia and Russian thistle were not controlled satisfactorily by any herbicide treatment or combination in 1966. Unlike results obtained in other locations, the herbicidal activity of EPTC was not improved by subsurface application as opposed to incorporation in the soil. Also, better weed control and less crop injury occurred when pebulate and R2063 were incorporated in the soil as compared with injection with knife-type applicators.

In Washington, R-2063 incorporated with the soil before planting sugarbeets provided excellent control of barnyardgrass, lambsquarters, and pigweeds, the major annual weeds in this crop in Washington. It caused only slight and temporary injury symptoms in the sugarbeets. In many respects, R-2063 appears superior to pebulate. R-2063 incorporated 2 or 3 inches deep in dry soil, or 3 or 4 inches deep in moist soil provided excellent control with slight crop injury. Surface application and incorporation 1-inch deep resulted in poor weed control, whereas subsurface layering 2 inches deep killed the sugarbeets as well as the weeds. Incorporation of pyrazon at depths of 2 and 3 inches killed sugarbeets as well as weeds. When layered beneath the surface or incorporated 1-inch deep, sugarbeet injury from pyrazon was less severe but weed control was also reduced. Pyrazon does not appear satisfactorily selective in sugarbeets in Washington. Post-thinning soil applications of trifluralin to weed-free sugarbeets provided weed control for the remainder of the season without harming the crop.

In Minnesota, a postemergence mixture of pyrazon with the experimental herbicide H634 again provided effective control for many broadleaf weeds in sugarbeets. The addition of a new herbicide, S-6173, to this mixture increased the effectiveness, and provided excellent control of many weeds that were too advanced for good control with the mixture of only two herbicides. Redroot pigweed is probably the most troublesome weed in sugarbeets in the North Central area at present. For this particular weed, saturated solutions of sodium chloride have appeared the most effective of all materials evaluated to date.

In Arizona, preplanting applications of IPC controlled wild oat and barley without injuring sugarbeets. Several other herbicides reduced stands or temporarily retarded growth of sugarbeets, but did not effect the total yield.

3. Control of Weeds in Sugarcane. For the second year in Louisiana, terbacil was as effective as fenac for preemergence control of johnsongrass seedlings and winter weeds in plant cane. Although cane treated with terbacil usually yielded higher than cane treated with fenac, one variety (C.P. 48-103) was visibly injured by terbacil. Postplanting incorporation of trifluralin with a rolling-cultivator implement controlled annual weeds and johnsongrass seedlings effectively without injury to the cane. Trifluralin incorporated approximately 8 inches deep before planting injured sugarcane severely. Chopping johnsongrass rhizomes into 1 and 2 node pieces with a power-driven rotary tiller increased the susceptibility of rhizome johnsongrass to picloram. For the third year, MSMA selectively controlled rhizome johnsongrass in stubble sugarcane. Early season applications of MSMA did not cause significant residues of arsenic in cane juice or fiber, but the treatments tended to increase arsenic content if applied after May. For the second year, heavy infestations of burclover and chickweed severely retarded the growth of plant sugarcane in the spring. Preemergence control of these winter weeds prevented yield reductions.

B. Nematodes in Sugar Crops

1. Sugarcane. In Louisiana, an organophosphate and an oxime at 4 pounds per acre increased sugarcane yields 4.5 tons per acre. These new chemicals were far superior to several other commonly used nematocides. Studies on organic amendments to soil continue to show that additions of 100 gallons per acre of molasses in-the-furrow reduced nematodes in sugarcane as much as a standard nematocide treatment. This year the molasses treatment increased sugarcane yields 6-8 tons per acre in test plots.

2. Sugarbeets. At the request of the Beet Sugar Development Foundation, a survey of waste disposal systems of five sugar factories in California was undertaken to determine if present systems allow dispersal of sugarbeet-cyst nematodes. Data show that cysts are being carried from the digestion and first settling ponds at some factories; viable cysts were recovered from two evaporation ponds at one factory, indicating the need for control of nematodes from waste systems of sugarbeet factories to prevent spread. Soil fumigation studies at Salinas, California, using a number of experimental nematocides established that a standard nematocide used alone or in combination with a new experimental material, increased yields of sugarbeets by 7.4 and 8.9 tons per acre, respectively. The standard halogenated hydrocarbon remains the most effective chemical for controlling the sugarbeet-cyst nematodes.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

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SUGARCANE AND SUGARBEET INSECTS
Entomology Research Division, ARS

Problem. Control of insects on sugarcane and sugarbeets is essential because of destructive plant diseases spread by insects and damage caused. The use of insecticides for insect control requires special care to avoid contamination of the harvested product with undesirable residues. Safe effective methods of control are especially needed for the sugarcane borer, the sugarbeet root maggot, and the beet webworm. Sugarcane mosaic has become more important in recent years, and information on insect vectors of this disease is needed. Beet yellows and associated western yellows virus diseases of sugarbeets continue to threaten the sugarbeet industry. Emergency chemical control measures for the aphid vectors of the viruses of these diseases are urgently needed. Studies on the ecology and methods of control of the weed reservoirs of the insects that transmit the two viruses should be continued. For long-range solutions to these problems, further investigations should be undertaken to find effective parasites and predators of sugar-crop pests and to develop varieties of sugarcane and sugarbeet that are resistant to insect attack. The usefulness of destruction of alternate host plants and new approaches to insect control, such as the male sterility technique and attractants, should be investigated. Research should aim to develop control methods without objectionable features. Key insect pests that require heavy use of insecticides for their control and thereby make the natural control of other pests on the same crops difficult are special problems that should receive emphasis in the search for nonchemical methods of control.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-range program involving basic and applied research on the insect problems of sugarcane and sugarbeet directed toward developing efficient and economical control methods. This program is cooperative with State and Federal entomologists, agronomists, and chemists in the States where research is underway and with industry. Studies on sugarcane insects are conducted at Houma, La., and Canal Point, Fla.; and on sugarbeet insects at Mesa, Ariz., Twin Falls, Idaho, and Yakima, Wash. Research on factors affecting the efficiency of Trichogramma spp. as parasites of lepidopterous pests is being conducted under a research grant with the Louisiana State University. Research on reproduction of beet leafhoppers is conducted under a grant in California. Cooperative agreements are being used to support research in North Dakota on control of sugarbeet root maggot and in Washington on plant resistance to yellows and its vectors.

The Federal scientific effort devoted to research in this area totals 9.5 scientists man-years. Of this number 1.6 is devoted to basic biology, physiology, and nutrition; 2.5 to insecticidal control; 0.7 to insecticide residue determinations; 1.7 to biological control; 0.4 to insect sterility, attractants, and other new approaches to control; 0.3 to evaluation of

equipment for insect detection and control; 0.6 to varietal evaluation for insect resistance; 1.0 to insect vectors of diseases; and 0.7 to program leadership.

Federal support of research in this area under grant provides for 0.3 professional man-year devoted to biological control, and 0.3 to basic biology of the beet leafhopper and under cooperative agreements for 0.3 man-year for control of sugarbeet root maggot and in cooperation with Crops Research Division for 0.3 for resistance studies.

Natural enemies of the sugarcane borer in India are being studied under a PL 480 project A7-ENT-1, by the Commonwealth Institute of Biological Control, Bangalore, India. Parasites and predators found effective for borer control will be made available foruse in the United States. A second PL 480 project, A7-ENT-22 has been initiated in India on studies of Indian Jassidae with particular reference to Circulifer and related genera and their importance as vectors of plant virus diseases.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 5.4 professional man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAM

A. Basic Biology, Physiology, and Nutrition

1. Sugarbeet Insects. At Twin Falls, Idaho, field studies near Rupert showed that most sugarbeet root maggots overwinter in the larval stage 6 to 9 inches below the soil surface. Root maggot flies emerged from the soil from May to August, the peak of emergence occurring in early June. This information provided basic information useful in timing field insecticide applications for control of adults of this pest insect.

Raw sugarbeet juice was more effective than other attractants used in the fly trapping. Other partially effective attractants were processed beet juice obtained from the sugar factory and a sugar solution. Male root maggot flies were sexually aggressive on the day of emergence whereas females were not receptive to mating until 3 days after emergence even though the newly emerged female flies contained a full complement of mature-sized eggs.

At Yakima, Wash., the ephydrid leaf miner, Psilopa leucostoma, a newly discovered pest of sugarbeets was found to attack the Halberd-leaved Orache, a saltbush, Atriplex hastata, and the common lambsquarters, Chenopodium album, and occurs throughout the intermountain region both in and outside of sugarbeet production areas.

At Yakima, a D-Vac(R) suction-type insect collector collected 6 times as many beet leafhoppersfrom sugarbeets as the standard sweep-net method. Sixteen kinds of leafhoppers were collected from sugarbeets. The beet leafhopper was most abundant and comprised 35% of the leafhopper population in July.

At the University of California, under USDA grant, a method was developed to differentiate sex of beet leafhopper nymphs based on the pattern of sclerotization of the ventral surface of the posterior abdominal segment.

2. Sugarcane Insects. In Louisiana the sugarcane borer infestation at harvest time in 1966 was 14% of the internodes bored or 4% less than 1965. Estimated crop loss due to borers was 11%. However, more borers overwintered in 1966-67 than normal due to an excessive amount of cane tops left in the field because of a severe freeze.

The sugarcane borer infestation in Florida (internodes bored) was 2.4% in 1966. This is slightly less than in the previous year.

Wireworms have become the most destructive sugarcane pests in Florida, and they caused serious reduction in stand of plant cane.

B. Insecticidal and Cultural Control

1. Sugarbeet Insects. Screening tests at Twin Falls, Idaho, against sugarbeet root maggot adults showed Bay 39007, diazinon, and azinphosmethyl to be the most promising insecticides for the control of this insect. These same insecticides were tested under field conditions near Rupert, Idaho, against flies of the sugarbeet root maggot and all gave promising results. Also several granular materials applied in a 6-inch band at planting time gave good control of the maggots. Granules of phorate and diazinon gave the best control but Bay 25141, Bay 37289, and Stauffer N-2790 were also effective.

An isolated area of 584 acres of sugarbeets near Rupert, Idaho was sprayed three times by airplane with undiluted technical malathion at the rate of 8 ounces per acre for control of root maggot flies. The sprays reduced the ensuing maggot population by 73% over the total area; maggots were reduced by nearly 100% in some fields. The first spray was applied 9 days after the first flies emerged. Results probably would have been much better had the weather permitted earlier application.

Two 1-lb applications of phorate, disulfoton, and Temik to the foliage of sugarbeets controlled aphids and increased yields 1 ton per acre at Yakima, Wash. This was of particular interest since the experiment was located within a 22 mi^2 area where overwintering forms of the green peach aphid and sources of beet western yellows had been drastically reduced by burning out overwintering hosts of aphids and virus in deep irrigation drains.

Curly top, transmitted by the beet leafhopper, caused more than the usual damage to sugarbeets in eastern Washington in 1966 and 1967. Curly top was most prevalent in late plantings. Foliage applications of phorate were more effective than demeton, disulfoton, oxydemetonmethyl, or Temik for control of the beet leafhopper.

Phorate proved more effective than disulfoton, demeton, oxydemetonmethyl, or Temik for control of the two-spotted spider mite on sugarbeets at Yakima, Wash. Although aphid treatments are applied in May and June, additional applications are required in July or August for mites. Foliage applications of Temik granules to sugarbeets gave better control of the green peach aphid and the potato aphid than disulfoton, phorate, demeton, or oxydemetonmethyl. In 1966, the green peach aphid was most abundant early in the season and the potato aphid the last half of the season. Temik also controlled lygus bugs for nearly 15 weeks and leaf miners for 21 weeks.

Experiments at Yakima, Wash., showed that the defoliation of peach trees the latter part of September with chemical defoliants reduced egg laying of the green peach aphid by 73%. The reduction caused by abscission of leaves before the oviparae aphids had crawled to the twigs was further augmented by increased syrphid predation.

2. Sugarcane Insects. Sixteen compounds were evaluated against the sugarcane borer, Diatraea saccharalis, in Louisiana. Percentages of control based on reductions in number of bored joints (internodes) ranged from 0 to 93. New insecticides showing the most promise for future use in the borer control program are American Cyanamid 47480, Dow M-3072, and Niagara NIA-10242 in granular formulations, and Abate, Azodrin, General Chemical GC-6506, and Shell SD-8447 in spray formulations.

Azodrin and azinphosmethyl both at 1/2 and one pound per acre for each of two applications as ultra low volume concentrates in an airplane experiment in Louisiana gave controls of 77 and 87% for Azodrin and 63 and 77% for azinphosmethyl at the respective dosage rates. Diazinon at one pound per acre gave only 23% control.

A survey of Azodrin-treated fields scattered over the sugarcane area of Louisiana showed infestations of less than 10% in 17 fields, with an average of 6.4% for 21 fields examined.

A comparison of automatic schedules of insecticide applications with a schedule of applications made when weekly examinations show 5% or more of the stalks infested with larvae feeding behind the leaf sheath showed no significant difference between the two methods, even though the number of applications were the same. These results are based on two years work and five field experiments in Louisiana.

Populations of the yellow sugarcane aphid (Sipha flava Forbes) increased enormously in Louisiana fields treated with carbaryl for borer control, regardless of dosage rates and formulations.

Studies of 10 insecticides for control of wireworms in Florida show the following 4 to be most promising: Stauffer N-2790 10% granules at rate of 3.8# active material per acre, Shell SD-9098 EC @ 4#, Niagara NIA-10242 10% granules @ 3.8#, and diazinon EC @ 4#. Results of 4 tests indicate little if any resistance of wireworms to parathion.

C. Insecticide Residue Determinations

1. Sugarbeet Insects. At Yakima, Wash., DDT, aldrin, and chlordane were applied in various doses to soil in 1965 but were not applied in 1966. One and a half years after application, the soil residues found were the following percentage of the initial residues: Aldrin (and dieldrin) 13, DDT (isomers and metabolites) 13, chlordane (isomers) 33. Residues in the harvested beet roots, calculated in terms of parts per million of residue in the roots for 1965 and 1966, respectively, were: Aldrin 0.04 and 0.003, DDT 0.013 and 0.008, chlordane 0.013 and 0.008.

D. Biological Control

1. Sugarbeet Insects. A big-eyed bug, Geocoris sp., was responsible for more than 50% mortality of eggs of the spinach leaf miner, Pegomya hyoscyami, on sugarbeets but this predator rarely attacked eggs of the ephydrid leaf miner, Psilopa leucostoma, at Yakima, Wash.

2. Sugarcane Insects. A small shipment of Trichogrammatoidea nana was received from the University of California for tests on the sugarcane borer in Louisiana. This species originally came from sugarcane borer eggs in India and is not known to occur in North America. It is particularly interesting since it and sugarcane may have evolved together. It readily parasitized eggs of our sugarcane borer, D. saccharalis, in the laboratory and parasitized 18% in a small field test.

In studies conducted at Louisiana State University under a grant, eggs of the sugarcane borer were unacceptable in the laboratory as a host by any of several strains of Trichogramma collected from various hosts. However, sugarcane borer eggs deposited naturally in the field were heavily parasitized.

Several Sycanus indagator, family Reduviidae, originating in India, were tested against larvae of the sugarcane borer in Louisiana. This predator readily accepted the borer and has been reared through one generation in the laboratory. The first field release is expected to be made in 1967.

Studies were continued of predaceous arthropod fauna in fields with past histories of high and low sugarcane borer infestations in Louisiana. In pitfall traps operated during the last three growing seasons, four general groups of predaceous arthropods were collected, namely: Ants, beetles, earwigs, and spiders. Ants, consisting of both native and imported fire ants appear to be responsible for low borer infestations.

More ants were always found in fields having low sugarcane borer infestations. For example, pitfall traps collected 312 ants in a field which had 6% internode infestation in 1965 compared to only 33 in a field which had 33% infestation and only one in a field with 50% infestation. When heptachlor was applied to a sugarcane field, ants collected in traps were reduced from 608 to 23. Fourteen weeks after treatment 36% of the joints in the treated field was infested as compared with 11% in the untreated field.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Sugarcane Insects. After laboratory tests showed that mating of the sugarcane borer occurred only below .04 foot candles of light, a small isolated cane field in Louisiana was flood-lighted in 1964, 65, and 66 to determine if the borer infestation could be reduced. As flashes of light were found to be just as good as constant light in the laboratory, tests were conducted under both conditions. Results indicate that neither constant or flashing light will noticeably reduce the borer infestation under field conditions.

The sugarcane borer is being successfully reared on an artificial diet at the Houma laboratory. Reared material is being used to increase parasites and predators in the laboratory for field release, and to infest cane varieties to determine their resistance to the borer.

F. Varietal Evaluation for Insect Resistance

1. Sugarbeet Insects. At Yakima, Wash., 4 of 31 varieties of sugarbeets were significantly more resistant to the beet- and beet-western yellows complex than the others. The variety grown commercially in eastern Washington was one of the four resistant varieties. The spinach leaf miner showed no particular preference for any of the 31 varieties tested. Three varieties showed some resistance to the green peach aphid.

2. Sugarcane Insects. Two hundred and eleven sugarcane varieties were tested for resistance to sugarcane borer in single plots under conditions of artificial infestation in Louisiana in 1966. Twelve of these varieties had infestations between 1/3 and 2/3 of average yields from 50 to 187% above average. Variety C.P. 66-491 with less than a third of the average infestation and 50% greater yield looks best. It also appeared good in previous tests. The stalk is large and has a high sugar content. Two other varieties showing considerable promise are H-60-386 with an infestation of 46% of average and a yield of 187% above average, and H-57-571 with an infestation of 49% of average and a yield of 163% above average.

Two hundred progeny from basic crosses and backcrosses involving wild (S. spontaneum and S. robustum) and cultivated canes made at Canal Point, Fla., and grown at Houma, La., were examined for borer infestation in the fall of 1966. These ranged from resistant to very susceptible. Three were very resistant and 21 otherswere moderately resistant. These 34 varieties were planted in a resistance test where they were subjected to artificial infestation in 1967.

G. Insect Vectors of Diseases

1. Sugarbeet Insects. At Mesa, Ariz., controlled infestations of curly top-infective beet leafhoppers on plots of sugarbeets grown for seed were accompanied not only by losses in yield but also late spring infestations reduced the percentage of viable seed.

A disease with symptoms similar to curly top was found in India (PL 480 project A7-ENT-22). Surveys for leafhoppers revealed the presence of several species of Circulifer.

2. Sugarcane Insects. Mosaic continues to be the most important disease of sugarcane in Louisiana. Since the disease is spread by insects, chemical control of insect vectors is being studied. In one experiment, 7 applications of diazinon and TDE reduced vector populations by 43 and 100% but had no effect on mosaic spread. In another test 4 applicationsof demeton gave 54% reduction in vector populations and reduced mosaic infection by 22%. Complete control of the rusty plum aphid, the only vector species for which sugarcane is a natural host, was obtained with all insecticides.

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CROP HARVESTING AND HANDLING OPERATIONS AND EQUIPMENT
Agricultural Engineering Research Division, ARS

Problem. Harvesting and farm handling of most crops are important items in the cost of production. In addition, the supply and adequacy of manpower for these operations is becoming progressively less satisfactory. Engineering research is needed in developing both equipment for precision application of herbicides and for the mechanical or cultural control of weeds. Also, the entire operational aspect of equipment for planting, producing, harvesting, and storaging of sugar beets should be reviewed.

The industry's Sugar Cane Harvesting Committee composed of eight members -- two each from Louisiana, Florida, Hawaii, and Puerto Rico -- has stressed the need for greater emphasis on research in the harvesting of recumbent sugarcane. High labor costs, along with the disappearance of farm labor in all domestic sugarcane areas, have accented the need for mechanical harvesting. Although an encouraging start has been made in this direction, economic problems have rendered present levels of research in this field inadequate. In addition to the problem of removing tops, leaves, trash, and extraneous material, Louisiana and Florida have the additional problem of removal of immature and frozen tops. There is need to develop methods of trash and top removal without regard to the point in the harvesting and handling of cane at which such methods might eventually be employed commercially. Possible points of trash and top removal are the mechanical harvester in the field, at transfer stations, or at the factory. In the case of Florida and Louisiana, a method of top removal is absolutely essential. In these two states, the top represents a larger percent of the total cane stalk and the top is more immature than in Hawaii and Puerto Rico. Furthermore, these two states are subject to freezes during harvest. Freeze-damaged top joints, if delivered to the factory, will close down the factory.

In two of three recent harvests in Louisiana, storm damage resulted in very badly lodged cane. Moreover, the present trend in the Louisiana industry is toward sugarcane varieties yielding more cane per acre and it is inevitable that this will lead to more "down" cane -- not less. Present harvesters are not designed either for harvesting down cane or for cleaning cane of this nature. The very high ratio of tops to millable cane makes this problem especially grave in Louisiana.

In Florida, sugarcane is largely cut and piled by hand. Adequate labor for this work cannot be recruited in the United States and the flow of labor from foreign areas is uncertain. The presently available harvesters will not do a creditable job of either harvesting the sugarcane grown in Florida or of cleaning it of tops and trash. Should foreign labor become unavailable, the industry would be dangerously lacking in means of harvesting its crop.

In Hawaii, cane is harvested mechanically by methods which cause both excessive sugar losses and exorbitant amounts of dirt and trash in the cane. Improvement in field harvesting and cheapening the cost of cleaning cane both depend upon development of better methods of doing these jobs.

In Puerto Rico, all of the cane is harvested by hand except for small quantities that are reaped by experimental harvesters. Harvest costs in the island have become so excessive that the development and adaptation of mechanical harvesters are essential to bring costs back in line with the limit sugar prices will support.

USDA AND COOPERATIVE PROGRAM

The Agricultural Engineering Research Division, ARS, has conducted research and development studies on sugarcane harvesting for a number of years. During most of this time the project was located in Houma, Louisiana. However, in 1964, with the appropriation of special funds for recumbent cane research, the project was moved to Belle Glade, Florida, and is conducted in cooperation with the Florida Experiment Station. In connection with the legislative history of this appropriation, arrangement was made for an industry committee to advise regarding the work to be carried out with this specification appropriation. The Florida area not only assured a better supply of recumbent cane but also had a longer harvesting season.

At about the same time the Belle Glade project was initiated, a 3-1/2 year contract was awarded to the Louisiana State University to study trash and top removal. This contract scheduled to expire in December 1967 has been extended until June 30, 1968. At that time other future approaches will be considered in cooperation with the industry's Sugar Cane Harvesting Committee. In order to maximize research effort, the equipment used in Louisiana has been transferred to Florida at the end of the harvesting season in Louisiana to take advantage of a later harvest and different conditions. It has been suggested that in the future, methods and machinery could be transferred to Hawaii and Puerto Rico if it seems feasible.

The Federal engineering effort of 2.0 SMY's is devoted to research on sugarcane.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

Sugarcane Harvesting Equipment

1. Auger-Type Pickup and Chopping System for Harvesting Recumbent-Type Sugarcane. A pickup system, incorporating two horizontal augers picking up and feeding the cane, was designed and field tested. The 20-inch outside diameter augers with 12-inch tube and 12-inch pitch pushed the cane to one side, picked it up with fingers mounted on the core, parted the cane from the adjacent row with a circular disk, fed the cane between the augers, and

chopped it into short lengths with the mating flights. The throat area of 7 inches x 6 feet between the augers turning at 100 r.p.m. was sufficient for a capacity of 1700 pounds per minute at operating speeds of 3.8 m.p.h. The auger speeds were increased to 133 r.p.m. and the apparent capacity was approximately 2300 pounds per minute at an operating speed of 5.75 m.p.h. The most serious problems with this system were (1) the need for location of the auger directly on the bottom cutter, and (2) the need for the discharge conveyor to be the same width as the augers. High-speed movies of the auger cutting action and discharge show that a nice clean cut is being made on the cane pieces. Some cane is fed through without being cut into short pieces when the flow of cane is light. The discharge of cane at the rear of the augers should not be any problem when a platform or conveyor is arranged to take it away as it flows. Further work will be done on an oriented finger to work in conjunction with the lower auger and with a solid platform behind the augers.

Evaluation of bottom cutters. As a continuation of the work last year, five additional types of bottom cutters at various speeds were evaluated through the use of high-speed photography. A 37-inch diameter rock blade and a 42-inch diameter cutter with rectangular segments, both installed on a Toft Australian harvester, were evaluated. These two cutters were travelling at speeds of 900-2400 f.p.m. These speeds did a poor job in recumbent cane in Florida, since the canes were not held in the rubber carrier chains while being cut as in erect cane. The double 26-inch notched circular cutters with augers were evaluated again after the manufacturer changed the blade as a result of the previous years' work. The removable sections with large notches and hard-surfaced edge did a much better job of cutting at ground level. The stalks were sheared without being pushed forward as was done previously. The double 24-inch bottom cutters, designed on the project, were evaluated with two types of sections at speeds of 5000-11,000 f.p.m. The heavy duty section with a 3/4-inch nose width did a better job of cutting than the 2-inch width section. At 11,000 f.p.m. with the 2-inch nose width, a considerable amount of chips or pulp was knocked from the cane stalk as it was being cut. It was evident that this range of speed was faster than necessary for cutting sugarcane stubble. The tip speed of between 5000 and 6000 f.p.m. was recommeded. The action of the bottom cutters was good as observed through the aid of high-speed movies. By turning both cutters inward, the cane was sheared together and the stubble remained more intact than with other types of cutters. The forward tilt of the cutters had to be increased to approximately 5° with the horizontal in order to decrease mutilation of the cane stubble.

Cleaning sugarcane on the conveyor. The experimental auger harvester cuts the cane into short pieces as it is being harvested and deposits it on a conveyor. Some leaf and dirt trash is separated from the cane by the augers and gathering fingers. An open mesh conveyor bottom removes soil and some small trash. One section of the conveyor has notched-tooth cleaners which are timed to operate through the conveyor slats, snagging leaves and tops which are pulled down through T-slots and discharged onto the ground. These cleaners have not proved to be aggressive enough to do effective cleaning. Additional speed on the notched fingers would improve cleaning, but to do this the timed conveyor slats would have to operate at an excessive speed.

Spiral roll cleaning and conveying. Two pairs of spiral rolls 68 inches long, of the kind used in sugar beet harvesters, were tried for cleaning and conveying sugarcane. These are made from 5-inch pipe wrapped with 5-inch pitch spirals of 5/8-inch rod. Several arrangements of rod and rolls were used. A final arrangement with the rods machined to a flat surface gave good cleaning and conveying up to 10°. At greater inclines, it would be necessary to hold the cane against the spirals. Rotations of 500-600 r.p.m. were used with the rolls mounted on the auger harvester to receive the discharge of the conveyor and to cross-convey the cane to a cane cart and to provide additional cleaning. Several other cleaning devices have been constructed and are being studied, including octagonal plate rolls, beaters, and flails. These could act as devices for loosening trash and dirt, holding cane against other cleaning equipment, and in moving the cane along the conveyor.

A reel-type cutting system. A system of harvesting cane using a large diameter horizontal reel was designed and field tested. This system was designed to cut into the cane from the top down and chop the cane into small pieces as it was cut loose at the ground. The reel was 4-feet wide and was 6 feet 6 inches in diameter to accomodate the tall canes. Reel tip speeds of 3400-8400 f.p.m. were tried with ground speeds of 1 and 3.8 m.p.h. The system was mounted on a harvester frame for field testing and was powered by an auxiliary engine. The results of the field tests indicate that the large reel will cut and chop cane with very little stoppages in the field. However, the resultant chopped material was not satisfactory as it contained approximately 30 percent trash. Observations of the cutting blade using high-speed photography indicated that the stalk being left by the cutting blade was sheared cleanly, but the piece chopped off and accelerated was being shattered by the blade. Two other modifications of the blades to eliminate the support which seemed to cause the shattering did not correct this sufficiently. Approximately 30 hp. was used to power the reel cutting one row of cane at a rate of approximately 1000 pounds per minute.

2. Mechanically Removing Tops and Leaf Trash from Sugarcane. During the 1966 harvest season in Louisiana, experimental sugarcane cleaners employing flat picking belts, a notched-tooth drum and brush arrangement, sets of square cleaning rolls, and sets of hexagonal cleaning rolls, were tested under a research contract with Louisiana State University. Each cleaning unit was designed in an effort to detach the tops and leaf trash which was not detached by chopping the mature stalks into short lengths. The picking belts removed from 30-40 percent of the total trash and from 55-75 percent of the loose trash. These removed few immature tops. The notched-tooth drum and brush cleaner removed approximately 58 percent of the total trash but lost a considerable amount of mature cane. The cleaning rolls were the most effective method of removing trash and both gave better results when positioned parallel to the flow of cane. The cleaning rolls removed from 50-75 percent of the total trash with the square rolls being the most aggressive and snapping more of the tops. Rubbing rolls were not effective in detaching trash from cane and an air blast did not improve the operation of any of the rolls. More work will be done with the cleaning rolls and notched-tooth drum and brush cleaner to improve effectiveness. When the same cleaners were operated in Florida, results were generally better. The square rolls removed up to 85 percent of the trash from mechanically harvested and topped cane. Snapping of immature tops was more difficult. Alternating pairs of rubber and steel corn husking rolls were very aggressive but did not prove as successful as the square rolls. Round rolls seemed to offer little advantage in cleaning.

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Sugarcane Harvesting Equipment

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II. NUTRITION, CONSUMER AND INDUSTRIAL USE RESEARCH

SWEET SORGHUM UTILIZATION - FOOD
Southern Utilization Research and Development Division, ARS

Problem. The Lower Rio Grande Valley, which is largely dependent on an agricultural economy, must have a greater selection of crops for diversification to meet unfavorable environmental and marketing conditions that frequently beset the area. Freezes and hurricanes have destroyed many citrus groves and generally retarded citrus production--a valuable source of farm income. Cotton, a mainstay crop, is also a surplus crop. In addition, yields in the Valley are frequently low, and insects and root rot pose troublesome problems. Many vegetables do well, but heavy losses have resulted from freezes, heavy rains, and maturation times that place Valley vegetables in direct market competition with those grown in other parts of the U. S.

Sweet sorghum has potential for becoming a profitable diversification crop. There are now available new disease-resistant varieties with high sugar content. This factor, together with favorable world sugar prices, has encouraged consideration of sweet sorghum canes as a potential sugar crop for the Valley. The modest water requirements of sorghum and the subtropical climatic conditions conducive to an extended growing season increase its attractiveness. In addition, preliminary studies in processing encourage evaluation of this crop for the production of sugar; its process integration with those for beet and sugarcane would extend the use of costly raw sugar installations.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving an organic chemist engaged at the U. S. Food Crops Utilization Research Laboratory, Weslaco, Texas, in investigations of methods for purifying sweet sorghum juices to permit practical recovery of their sugar content. Close cooperation is maintained with Substation 15, Texas Agricultural Experiment Station, Weslaco, Texas, in growing and harvesting the breeding stock provided by the Crops Research Division.

The Federal scientific effort at the Southern Division devoted to research in this area totals 1.3 scientific man-years. All of this effort is on chemical composition and physical properties.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 6.0 scientific man-years is devoted to sweet sorghum and sugar crops utilization research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Investigations of Chemical Characteristics of Sweet Sorghum to Evaluate Its Potential for Recovery of Sugar. Analysis of sweet sorghum field samples from the 1966 harvest are nearly complete. Because of their respective 1966 climates, sugar yields per ton of stalks were superior in the San Antonio-Winter Garden area but low in Weslaco; conversely, stalk tonnages per acre were low for the former but high for the latter, so that the values of sugar per acre were similar for the two areas. Modification of an analytical procedure for measuring the juice free acidity of field samples has permitted estimation of the clarification performance of such juices. One lot of sweet sorghum juice provided by the diffusion of finely chopped low sucrose silage-type stalks (with leaves) in the factory facilities of a sugar beet company was successfully clarified by the procedure proposed as a result of previous research. Data derived in this research have indicated approaches of significant value both in the selection of breeding lines and horticultural practices and in establishing suitable processing techniques. This information is being developed in cooperation with the Texas Agricultural Experiment Station at Weslaco and the Crops Research Division. (S5 5-51, S5 5-55).

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

None.

Utilization research on sugarbeets at Western Utilization Research Laboratory was discontinued at the end of Fiscal Year 1965. The following publications pertain to the research prior to its termination:

Sugar Beets

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Avigad, Gad. 1966. Inhibition of glucose 6-phosphate dehydrogenase by adenosine 5'-triphosphate. National Acad. Sci. Proc. 56(5):1543-1547. 1/

Avigad, G. 1966. Preparation of 6-^{3}H-D-galactosides, 6-^{3}H-D-galactose, 5-^{3}H-D-fructose and 5-^{3}H-L-sorbose. Israel Chemical Soc. Proc. and Israel Jour. of Chemistry Vol. 4. 1/

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Lowe, E., Stark, J. B., and Schultz, W. G. 1967. Engineering analysis of ion exclusion for sucrose recovery from beet molasses. Part II. Data analysis and cost projection. International Sugar Jour. 69:104-107.

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McCready, R. M., Goodban, A. E., Ratner, Rachel, and Ulrich, Albert. 1966. Sugar beet and purified juice quality in relation to non-sugar constituents. J. Amer. Soc. Sugar Beet Technol. 14(2):91-96.

Schultz, W. G., Stark, J. B., and Lowe, E. 1967. Engineering analysis of ion exclusion for sucrose recovery from beet molasses. Part 1. Experimental procedures and data reduction techniques. Internatl. Sugar Jour. 69(818)35-38.

Walker, H. G., Jr. and McCready, R. M. 1966. Some substances adsorbed on granular carbon from beet thick juice. J. Amer. Soc. Sugar Beet Technol. 14(2):142-46.

1/ Research supported by P. L. 480 funds.

NUTRITION AND CONSUMER USE RESEARCH
Consumer and Food Economics Research Division, ARS
Human Nutrition Research Division, ARS

Problem. The assortment and characteristics of food available to consumers change constantly with the adoption of new practices of production, processing, and marketing. Changing constantly also, as nutrition science advances, is our understanding of the nutritional needs of man and the manner in which these needs can best be met by food. To help meet the Department's responsibility to advise consumers on the quantity and variety of foods that will assure maximum benefit and satisfaction, research must continue on the nutritional requirements of persons of all age groups, on the nutrient and other values of foods, and on ways to conserve or enhance these values in household and institutional preparation and processing.

The kinds and amounts of foods consumed by different individuals and population groups must be determined periodically so that the nutritional adequacy of diets can be evaluated. Information on food consumption and dietary levels provides the guidelines needed for effective consumer nutrition programs. This information also furnishes the basis for market analyses for different commodities and for development and evaluation of agricultural policies and programs that relate to production, distribution, and consumer use of food.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing program of research concerned with (1) nutritive and other consumer values of raw and processed foods as measured by chemical or physical means and by biologic response; (2) effects of household practices upon the nutritive values and inherent qualities of foods, and the development of improved procedures for household food preparation, care and preservation; (3) nutritional appraisal of food supplies and diets of different population groups; and (4) development of guidance materials for nutrition programs.

The research is carried out by two divisions of the Agricultural Research Service--the Human Nutrition Research Division at Beltsville, Maryland and the Consumer and Food Economics Research Division at Hyattsville and Beltsville, Maryland and Knoxville, Tennessee. Some of the research in both divisions is done under cooperative, contract or grant arrangements with state experiment stations, universities, medical schools, hospitals, research institutes, and industry. The total Federal scientific effort devoted to research in these areas is 81.7 man-years. It is estimated that 1.0 scientist man-year is concerned with studies related to sugar.

Human metabolic studies and the related exploratory and confirmatory studies with experimental animals and microorganisms concerned with defining human requirements for nutrients and foods are not reported on a commodity basis, though some of the work is applicable to this report. This basic nutrition

research represents a total Federal effort of 19.8 scientific man-years and is described in detail in the report of the Human Nutrition Research Division. Certain aspects of this research related to dietary carbohydrates are considered briefly in this report.

PROGRESS--USDA AND COOPERATIVE PROGRAMS

A. Nutritional Evaluation of Dietary Carbohydrates

Research in the Department and elsewhere has provided evidence that the kind of carbohydrate in the diet may influence metabolism under some conditions, and that the changes may be due to an interaction with other dietary ingredients. Research is continuing to find out more about the interactions of fats, proteins, and minerals with different kinds and amounts of carbohydrates, their effects on body composition, and on the structure and functioning of tissues at various stages of the life cycle.

1. Kind of carbohydrate. A dietaty study with 10 young men (19-23 years old) was conducted to compare the nutritional value of wheat starch with sucrose. In this study, the young men ate diets identical in composition to those in an earlier study of young women reported in the 1966 Report (p. 38). In these diets, 85 percent of the carbohydrate was provided by wheat starch or sucrose during 30-day dietary periods. To meet the greater nutrient needs of the young men, the quantity of all foods in the diet was increased by approximately 50 percent over the quantity eaten by the women. The men's serum levels of lactate dehydrogenase, alkaline phosphatase, aldolase, and the two transaminases were significantly higher with the sugar diet than with the starch diet. Most of the levels observed were within the normal range for the enzyme under study. The levels of aldolase were in the border-line area (slightly above normal) in three subjects initially, in two subjects after eating the starch diet, and in seven subjects after eating the sugar diet. The significance of these observations is not clear at present, but it seems likely that starch and sugar were metabolized by different pathways or at different metabolic rates or both. A portion of this research was reported at the Federation of American Societies for Experimental Biology in Chicago, April 1967. A manuscript is being prepared.

To help explain some of these observations, research on the early metabolic effects of different kinds of carbohydrates upon various components of blood and urine of men and women has been initiated under a grant at the University of Alabama. The carbohydrates proposed for study include glucose, fructose, sucrose, wheat starch, and cornstarch. Blood will be analyzed for changes in enzymes such as lactate dehydrogenase and its isozymes and for carbohydrate metabolites such as glucose and pyruvic acid for several hours following the test meal. Urine will be analyzed for various nitrogenous components and mineral elements.

Scientists in Israel, supported by a PL 480 grant from USDA, have extended their research on the influence of the kind of carbohydrate on fat and cholesterol in the blood to include fructose in addition to glucose, sucrose, and cornstarch. They are investigating subjects with normal levels of fat

and cholesterol in their blood as well as those with abnormally high levels of both. Only certain subjects responded with marked changes in the triglyceride and cholesterol levels in the blood when different mono- or disaccharides were interchanged with starch. A possible derangement in carbohydrate or fat metabolism by these subjects is suggested. The kind of differences observed are in line with those found in investigations currently underway in the Human Nutrition Research Division with different strains of rats and may well be related to inherited traits of the subjects.

2. Influence of heredity. Research at Beltsville is providing evidence that protein and mineral metabolism as well as lipid metabolism may differ with the kind of carbohydrate in the diet and that the response may vary with the inherited characteristics of the animals under investigation.

During this year, four papers have been completed reporting the results of the long-term feeding of cholesterol-containing diets with the carbohydrate supplied as sucrose, glucose, and cornstarch. The findings dealing with the liver and serum lipids and the histology were described in the 1966 Report, p. 39. The paper dealing with the influence of type of dietary carbohydrate on the histological findings has been accepted for publication in the Archives of Pathology. A paper dealing with the effect of dietary carbohydrate on serum protein components has been accepted for publication in the Journal of Nutrition. A manuscript on the effect of type of dietary carbohydrate and age on magnesium, calcium, and phosphorus metabolism has been prepared. A fifth paper is in preparation and will include the results on food intake, weight gain, and body composition as influenced by the kind of dietary carbohydrate.

The influence of the kind of carbohydrate on the protein components in the blood depended on age, state of fast, and strain of rat investigated. The greatest differences were observed in a protein component (PA) moving more rapidly than albumin in an electric field. The incidence, that is the relative number of rats containing this component in their blood, as well as the level of PA in the blood varied with the experimental conditions.

Differences due to dietary carbohydrate were seen more frequently in the blood obtained from rats after an overnight fast than from nonfasted animals. In one strain (BHE), level and incidence of PA increased with age in the blood of fasted animals that had received the diets containing sucrose or starch. Extremely high levels were observed with sucrose. With glucose, the incidence was high at both 150 and 350 days of age, but the level was consistently low. In a second strain of rats (Wistar) fed sucrose, the level and incidence of PA were both high at 150 days, but low at 350 days; by 350 days no significant differences due to carbohydrate were apparent. The level of PA in the blood correlated directly with the level of fat in the blood, suggesting that this component, previously shown to be associated with fat, may play a role in fat transport.

The kind of carbohydrate also was found to influence significantly the calcium and magnesium content of the kidneys of the BHE rats. Here, too, heredity was apparently a factor in determining the extent to which levels of kidney calcium differed with dietary carbohydrate. Calcium levels were higher in the kidneys of BHE rats when the diet contained sucrose than when

the diet contained starch. When sucrose was fed, the level of calcium was much lower in the kidneys of the Wistar rat than in the kidneys of the BHE rat, a strain generally susceptible to kidney damage and dying at an early age on this diet. The magnesium levels in the kidneys of both strains were higher in the animals fed sucrose than in those fed starch but no differences due to heredity were observed.

A project initiated last year under contract with the Hazleton Laboratories at Falls Church, Virginia, is progressing rapidly and close contact with the developments from this research has been possible because of the computer facilities available at the Hazleton Laboratories. This investigation is providing more information on heredity as a factor in response to diet as well as further evidence of differences in fat metabolism with the kind of dietary carbohydrate.

3. Protein-carbohydrate interrelationships. Research using a protozoan, Tetrahymena pyriformis, with nutritional requirements and metabolic responses similar to those of higher animals, is providing further evidence concerning carbohydrate and nitrogen relationships. The marked inhibition of this organism by the amino acid serine has been found (1) to be related to type of carbohydrate, (2) to be affected by past dietary history, and (3) to be overcome as the length of the incubation period is prolonged. When the medium contains glucose, inhibition is slight; the presence or absence of glucose in previous culture media has little effect on growth response. In contrast, when the carbohydrate is dextrin, inhibition by serine is pronounced, and was greater with cultures which had previously been maintained on media containing glucose or dextrin. The inhibition is largely reversed by intermediates of the citric acid cycle, by amino acids that enter readily into this cycle, by pyruvic acid, and by glucose.

B. Tables of Food Composition

1. B-vitamins in foods. Summarization of data and derivation of representative values for a publication on pantothenic acid, vitamin B_6 and vitamin B_{12} are now complete for some 700 items of food. The values will provide the basis for evaluating food supplies and diets with respect to these vitamins.

2. Nutritive value of retail and household units of food. The development for publication of a table showing nutritive values of foods in terms of common retail and household units is continuing. Values will be given for proximate composition, calcium, phosphorus, iron, sodium, potassium, vitamin A, thiamine, riboflavin, niacin, ascorbic acid, and selected fatty acids. Final values are ready for more than 500 items of food and are nearing completion for others.

3. Revision of Handbook No. 8. Work to obtain data for the next revision of Agriculture Handbook No. 8, Composition of Foods, is proceeding along several lines.

C. Food Consumption and Diet Appraisal

1. 1965 nationwide survey. Analysis of the household data showed that families surveyed in the spring of 1965 spent 36 cents of their food dollar for meat, poultry, fish and eggs; 19 cents for vegetables and fruits, including juices; 13 cents for milk and milk products; 12 cents for flour, cereals, and bakery products; 10 cents for beverages other than milk and juice; and 10 cents for fats, sweets and all other foods. This division of the food dollar varied little among groups of families whether classified by region, urbanization or income. Choices within these broad groups did vary. For example, farm families used more flour, fat, sugar, and eggs per person and less bakery products than city families. Southern families used the most pork, poultry and fish and the least beef; western families used the most beef.

Families surveyed in the spring of 1965 used more beef and poultry and less pork, fish and eggs than families surveyed in the spring of 1955. The families surveyed in 1965 also used more frozen milk desserts, cheese, dry and fresh skim milk and less fresh whole milk, cream, and evaporated milk; more canned and frozen vegetables and fruits and less fresh vegetables and fruits; more breakfast cereals and bakery products other than bread and less flour, bread and cereals other than breakfast cereals; more margarine and oils and less butter and shortening. Many of the changes reflected the trend to increased use of commercially prepared foods. There was also greater use in 1965 of foods associated with snacking--ades and punches, soft drinks, potato chips, luncheon meat, peanut butter, crackers, cookies, doughnuts and candy.

Papers reporting findings on the food consumption of households in spring 1965 were presented at three National meetings. One preliminary report was published and a second was prepared for publication. Final reports are in preparation--one for the U.S. as a whole and one for each of the four census regions. These reports will provide information on the percentage of families using major groups, subgroups, and selected items of foods as well as the quantities and money value of the foods consumed. The information will be given separately for urban, rural nonfarm, and rural farm families and for all urbanizations combined. Another classification will be by income of family.

2. 1967 survey in Mississippi. In May 1967, a survey was made to evaluate two types of food distribution programs in two counties in the Mississippi Delta. The survey was made by the Consumer and Food Economics Research Division, ARS, in cooperation with the Economic Research Service. In Washington County, a Food Stamp Program had replaced a Food Donation Program in March 1967. In Sunflower County, a Food Donation Program of long standing was in operation. The families surveyed included participants and eligible nonparticipants in both the Food Stamp Program and the Food Donation Program.

Preliminary evaluation of the data indicated that the average diet was poor. Foods most needed to improve the diets of these families are milk products,

vegetables and fruits. Diets of families who participated in the food programs were similar in many respects to diets of those who were eligible but did not participate.

Money value of the food used averaged about $4.00 a person a week (including value of free food stamps and donated commodities). This is about 25 percent less than the cost of the USDA Low-cost Food Plan for the South. On the average the families included in the survey spend about one-half of their incomes on food.

Data on height and weight were obtained as an indication of the growth and nutritional status of children 2 to 12 years old in the families surveyed and are being evaluated by the Human Nutrition Research Division. Preliminary results indicate that the children tended to be somewhat short for ther age and also heavy for their age and for their height. Children in families that were participating in a food program were no different in height and weight for age than children in nonparticipating families.

3. Preschool children in Hawaii. Data needed to assess the nutritional situation of children 2 to 3 years of age in low-income families and middle-income families in Honolulu have been collected. Included are a 3-day record of the child's food intake, a physical examination record, and information on the child's early diet, on the mother's food practices and attitudes, and on the family's socioeconomic situation. Data collected in biochemical, clinical, and psychomotor tests are being evaluated. The research is being carried out by the University of Hawaii under cooperative agreement with the Consumer and Food Economics and the Human Nutrition Research Divisions.

4. Nutritive value of the national food supply. Food energy (calories) and selected nutrients provided by the per capita food supply are estimated each year by the Consumer and Food Economics Research Division from data on apparent civilian consumption, retail basis, developed by the Economic Research Service. The estimates show that shifts in food consumption over the years have resulted in changes in the sources of fat, carbohydrate and protein. Vegetable fat now accounts for a higher percentage of total fat because of the shift from butter to margarine and from lard to shortening and the sharp increase in use of salad and cooking oils. The share of calories derived from total nutrient fat which increased from 1909 to the early 50's has changed little since. Saturated fatty acids account for a smaller share of the total fat today than they did 55 years ago--37 percent compared with 40 percent--even though the American diet now contains more fat. Oleic acid continues to account for about 41 percent of the total fat. The share attributed to linoleic acid has been increasing and is now roughly 13 percent. Starch and sugars now contribute about equally to total carbohydrates; in 1909-13, two-thirds was provided by starch and one-third by sugars. Animal products contribute two-thirds of the protein today compared to one-half 55 years ago.

5. Nutrient content of school lunches. A nationwide study of the nutrient content of Type A lunches served to 6th graders is being carried out by the

Consumer and Food Economics Research Division in cooperation with the School Lunch Division, Consumer and Marketing Service. The study was undertaken to obtain data needed for evaluating the Type A pattern. Twenty lunch composites from each of 300 schools in 19 states in 5 geographic regions have been analyzed by a contractor, the Wisconsin Research Alumni Foundation, for proximate composition, fatty acids, and 12 minerals. Analyses are in progress for seven vitamins, iron and residues of chlorinated hydrocarbon insecticides.

In general, the lunches met the nutritional goal of one-third of the 1963 NRC Recommended Daily Dietary Allowance for 9 to 12 year olds for energy, calcium and protein. The average energy level of the lunches from the 300 schools was 735 Calories--the goal for girls and a little under the goal of 800 Calories for boys. On the average, 39 percent of the calories were provided by fat in the lunches. The average calcium content was 400 milligrams per lunch--a little more than the goal of 367 milligrams. For protein, all lunches met the goal of one-third of the Recommended Daily Allowance for 9 to 12 year olds--18.3 grams for girls and 20 grams for boys.

6. Acceptance of Type A lunches. A study of factors affecting acceptance of the lunch program by 10th grade students in Louisiana is being carried out under cooperative agreement with Louisiana State University. Thirty students from each of 17 schools, their parents and the officials of the schools provided information for the study. Included were urban and rural schools, large and small schools, and schools with low, medium and high levels of participation in the lunch program.

D. Support for Food and Nutrition Programs

1. The fifth national Nutrition Education Conference was held in Washington, D.C., February 20-22, 1967, with about 275 persons representing a wide variety of agencies and disciplines from most of the states. The theme was "effective communication" and coordination of nutrition programs as a means of facilitating behavioral changes in eating habits. The Conference was cosponsored by the Consumer and Food Economics Research Division and the Interagency Committee on Nutrition Education.

2. Bimonthly publication of Nutrition Program News, which reaches some 7,000 workers in nutrition and related fields was continued.

3. Technical assistance to programs. Nutrition research findings continue to be studied and interpreted for application to problems in food selection and food use. Technical assistance was given by nutritionists to programs of other government agencies such as the food and nutrition programs of Project Head Start, Office of Economic Opportunity. Talks to groups involved in community nutrition programs, radio and TV tapes on nutrition, and consultant help and participation in conferences contributed to coordination and strengthening of nutrition programs.

A 130-page manual prepared by the Human Nutrition Research Division for the Head Start Program of the Office of Economic Opportunity gives quantity recipes and food buying guides needed to prepare nutritionally adequate meals for groups of 25, 50, or more preschool children from low-income families.

4. Food for low-income families. Recipes were developed for selected commodities for distribution to low-income families participating in the USDA food distribution program or the Food Stamp Program. These supplement the earlier series of 17 leaflets on a variety of commodities now available for national distribution as part of the Department's participation in the Federal program to combat poverty.

5. National school lunch program. Research on large quantity food preparation and food quality in the Human Nutrition Research Division has provided help to school lunch managers across the nation to make the best use of donated food commodities available to them and other foods obtained on the local market. A survey of pupil acceptance of "favorite" recipes in about 100 schools in five areas in the United States is in progress.

PUBLICATIONS--USDA AND COOPERATIVE PROGRAMS

Nutritional Value of Carbohydrates

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Nutritive Value of National Food Supply

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Food Consumption and Dietary Levels

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Gilpin, G. L., and Merrill, A. L. 1966. Protecting food quality in the home. Chapter in 1966 Yearbook of Agriculture, pp. 170-178.

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III. MARKETING AND ECONOMIC RESEARCH

ECONOMICS OF MARKETING
Marketing Economics Division, ERS

Problem: The market for sugar in the United States, as well as much of the world, is highly regulated. After about 145 years of congressional actions affecting the sugar industry, the first Sugar Act was passed in 1934 known as the Jones-Costigan Act. It embodied three major objectives: (1) to maintain a healthy domestic industry of limited size, (2) to promote our general export trade, and (3) to assure adequate supplies of sugar to consumers at reasonable and stable prices.

Succeeding sugar legislation has maintained the basic philosophy of the Act. The Act contained six principal means for dealing with the sugar problem. These were:

1. The determination each year of the quantity of sugar needed, at prices reasonable to consumers and fair to producers.

2. The division of the U. S. sugar market among the domestic and foreign supplying areas by the use of quotas.

3. The allotment of these quotas among the various processors in each area.

4. The adjustment of production in each area to the established quotas.

5. The levying of a tax on the processing of sugarcane and sugarbeets, with the proceeds to be used to make payments to producers to compensate them for adjusting their production to marketing quotas and to augment their income.

6. The equitable division of sugar returns among beet and cane processors, growers, and farm workers.

Annual sugar production in the world has been around 70 million short tons. World consumption has been increasing at a slower rate than production. The government of nearly every sugar-producing country exercises some degree of control over the production, refining, and marketing of sugar.

In the United States annual per capita consumption averages about 97 lbs. When the sugar program became effective in 1934, the mainland cane and beet producers were supplying only 28% of the domestic market. Today the mainland produces 41% of our needs, with the comestic areas of Hawaii, Puerto Rico, and the Virgin Islands supplying an additional 18%. The balance, almost all cane, is imported. The price of sugar in the U. S.

is lower than in most every country that does not produce its own total sugar needs. The sugar program has assured the consumer of a constant and adequate supply of sugar. At the same time, the price of sugar has increased by only 26% in the last eighteen years, whereas the cost of all food in the U. S. has increased by 35%.

In implementing the intent of the Sugar Act, the Secretary of Agriculture is required to determine, between October 1 and December 31, how much sugar will be needed by consumers in the continental United States during the next calendar year. He takes into consideration the amount of sugar used during the preceeding twelve months, the current sugar inventory, and prospective changes in population and demand conditions. Finally, he must estimate the next year's sugar price and index of prices paid by farmers in order to set a requirement figure that will not result in excessively high or low sugar prices.

The next step is dividing the required quantity among domestic and foreign producers. This allocation is made by statutory formula. The domestic quota is adjustable upward if the Secretary's estimate of requirements exceeds 10.4 million tons, and downward if requirements are less than 9.7 million tons. During the last few years the U. S. quota in millions of tons has been as follows: 9.2 in 1965, 9.8 in 1966, 10.2 adjusted to 10.6 in 1967, and 10.4 announced in December 1967 for 1968. The allocation is roughly 3,000,000+ tons to sugarbeet growers and 1,000,000+ tons to sugarcane growers.

USDA AND COOPERATIVE PROGRAMS

The USDA has the equivalent of slightly more than two scientist man-years devoted to research on sugar marketing. The effort has been devoted to analyzing the effect of nonsugar sweeteners from a competitive standpoint and recently has cooperated on an informal basis with several State Experiment Stations on marketing of raw material, namely, beets and cane. The objective of the latter is to measure the effect of changes in price of sugarbeets and sugarcane on the number of acres of these crops farmers in a given region would choose to grow.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

Competitive Situation of Input and Output Marketing Firms

Research in this area is concerned with the organizational characteristics and practices of marketing firms which affect competition among firms and their relative bargaining position as both buyers and sellers. Studies relate to the measurement and evaluation of concentration, mergers and the various dimensions of integration and diversification of firms. These factors assist in evaluating the marketing position or power of the inter-

mediary marketing agencies. Information on profit ratios and descriptive statistics relating to the farm-retail price spreads and the Marketing Bill serve as benchmark indicators of market position and power.

Sugar

Since 1956 marketings of beet sugar have increased in volume more rapidly than total sugar marketings. This has increased the average cost of marketing a pound of beet sugar, primarily because of increased transportation costs. Since the price growers receive for sugarbeets is largely dependent on the net returns (price minus marketing expenses) processors receive for their sugar, prices for sugarbeets have not risen as much in recent years as have prices for refined cane sugar in New York. An increase of 1% in the share beet sugar constitutes of total United States sugar supplies is associated with an average decline of 0.14 cent per pound in the amount by which sugarbeet processors net returns were below refined sugar prices in New York. This is equivalent to about 26 cents per ton of sugarbeets.

Sugar's share of the market for the major sweeteners -- sugar, corn sweeteners and noncaloric sweeteners -- has declined from about 87% of the total in 1957 to 81% in 1965. The growth of nonsugar sweeteners has been especially important in food industries manufacturing ice cream, soft drinks and canned fruit. Further increases in the use of nonsugar sweeteners appear likely.

A study of the position of noncaloric sweeteners in the sweetener industry shows that about two-thirds of the sales of soft drinks manufactured with noncaloric sweeteners in the United States represented additional sales and only one-third were used as a substitute for sugar-sweetened soft drinks. The extent of substitution probably was somewhat less in most other uses.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

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